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SUGGESTED APPLICATION OF CARTOGRAPHIC TECHNIQUES TO TOPOGRAPHICAL MAPPING IN LESS DEVELOPED AREAS

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SUGGESTED APPLICATION OF CARTOGRAPHIC TECHNIQUES TO TOPOGRAPHICAL MAPPING IN LESS DEVELOPED AREAS

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INTRODUCTION

1. Despite the amount of literature on survey and mapping techniques, conferences similar to this one have been held at regular intervals on continental, regional and fully international levels. From this fact, one can deduce that representatives of the developing countries are seeking suggestions as to how they can best solve their problems.

2. The problems are primarily these:

(a) An inadequate or non-existent triangulation framework;

(b) Shortage of trained personnel;

(c) Urgency with which maps must be provided for development purposes.

3. In seeking a solution, resort is made to a study of what other countries are doing, only to find that the majority of them have a considerably greater national income, long-established cartographic organisations and have reached the present state of mapping over a period of several decades.

4. This paper suggests that it is not only vital to apply modern techniques, but also most important to have a definite stated policy so that available resources may be applied with concentration to meet the needs of the country.

5. It is recommended that this policy be implemented in three phases as follows:

(a) first phase: to provide for the minimum essentials;

(b) second phase: to provide for the further necessities;

(c) third phase: to provide for overall improvement.

6. It is also recommended that modern techniques be used in the prosecution of the various programmes.

GEODETIC SURVEY

7. It is generally acknowledged that a framework of permanently marked

stations, fixed in position and height on a national system, and a network of precise level bench marks are essential to serve as control for subsequent surveys and mapping, which latter, in turn, are essential for the planned development of the country. Wasteful unconnected surveys are eliminated where a national triangulation is in existence.

8. Primary triangulation sides average between 20 and 30 miles in length, which gives a density of about one point in every 500 square miles. This density is sufficient for 1/50,000 mapping when modern techniques are used. Secondary and tertiary triangulation, which provide the density of control required for larger scale mapping and for detailed surveys, are obtained by successive break-downs from the primary triangulation. Similar orders of precise levelling provide the framework of level bench marks.

9. It is recommended that the implementation of the policy in respect of the geodetic survey be

(a) first phase: to complete as soon as possible the primary triangulation and precise levelling over the whole country;

(b) second and third phases: to extend the secondary and tertiary triangulation and precise levelling. Circumstances may require that some secondary and tertiary triangulation and levelling be provided in selected areas during the first phase.

10. It will not be possible to delay a start on the mapping and other survey operations until the whole country has been covered by the primary triangulation, so the plan will have to recognise and provide for the fact that isolated control surveys may have to be performed and that the primary triangulation will have to be undertaken simultaneously in different sections situated in widely separated parts of the country. Isolated control surveys should be undertaken in such a way that they can be connected to or form part of, the main framework when it is extended into the region. The different primary nets should likewise be undertaken in such a way that they will form parts of the framework of primary triangulation of the whole country.

11. If geodetic chains have been completed, the primary triangulation can be proceeded with straight away but if not, the geodetic control for the primary triangulation will have to be provided first. It is desirable that the primary triangulation conform to the accepted standards of accuracy in order to form a solid basis for current needs and for the needs of the foreseeable future. Where the geodetic control is to be provided first, a decision will have to be taken, on the merits of each case, as to whether classical methods will be used, thus ensuring the accuracy of the subsequent primary triangulation, or whether use will be made of the less accurate but far more rapid method of trilateration using the "line crossing" method of measuring sides with electronic measuring devices. If this latter method is used, geodetic stations can be established from 150 to 250 miles apart, depending on the type of equipment used. For many countries, therefore, the geodetic "chain" would consist of a single polygon made up of a number of quadrilateral figures with an origin station roughly in the middle of the country. It may be advisable for this work to be undertaken on a contract basis by a concern equipped for and experienced in, such undertakings.

12. Whether the classical method of measuring the angles of the triangles by theodolite or whether the trilateration method of measuring the sides by means of measuring devices utilising either radio or light waves is used for the primary network, will have to be decided on the merits of each case. Each has advantages over the other in different sets of circumstances.

13. The combined cost of reconnaissance, observing and adjustment is about £300, £100 and £50 per station for the three orders of triangulation respectively, which constitutes a considerable investment of money, so the permanent marking of the triangulation stations is obvious. Since considerable use will be made of daylight observations directly onto the triangulation stations, distinctive opaque markers are essential. A 4 ft. high cylindrical concrete column with a removable sighting vane can be built over a centre mark in situ at an average cost of about £25. At lease three witness marks must be placed and be measured to, so that the centre mark can be recovered accurately should the beacon be destroyed.

14. The precise levels should preferably be referred to mean sea level by direct connections to tide gauges or by connections to benchmarks in adjoining territories which are based on mean sea level. If this is not possible, a national datum must be chosen to which all levels and heights will refer. Permanent benchmarks should be placed every half-mile with a battery of three, one of which is considered as a fundamental benchmark, every 30 to 35 miles. Each section of the route must be levelled twice, i.e. in opposite directions. One leveller using a geodetic level with parallel plate and invar staves can average about 125 miles of such double levelling a year to primary levelling accuracy. Connections to triangulation beacons should be made wherever possible in order to increase the reliability of the trigonometrical heights. Automatic level instruments can be used for secondary and tertiary precise levelling.

AERIAL PHOTOGRAPHY

15. Aerial photographs are essential for modern mapping techniques. In addition, individual photographs and photo mosaics are planimetric topographical maps of a sort in themselves, which can be used for study purposes and from which much valuable information can be gleaned. Measurements, albeit of low accuracy, can be made on them. Relief can be studied from stereoscopic pairs viewed through a stereoscope. They are invaluable to geologists and many other scientists. Thus the provision of aerial photographic cover of the whole country is a high priority requirement in the first phase of the cartographic policy.

16. Some of the factors affecting the specification for the aerial photography are the following:

(a) the scales of the maps to be produced from the photographs and the mapping techniques which will be used;

(b) the value of the photographs as temporary planimetric maps;

(c) the needs of the user, particularly regarding the scale of the photography;

(d) the photographic cover is required quickly and economically;

(e) priorities will necessitate the building up of eventual full cover of the country by way of isolated blocks of photography.

17. The 1/50,000 and 1/250,000 map series and the use of modern photogrammetric techniques are recommended in paragraph 21(a) for the first phase mapping programme. It is suggested, therefore, that the first phase aerial photography be

(a) super wide-angle vertical photography to a scale of 1/70,000;

(b) tilts not exceeding 2°;

(c) fore-and-aft overlap to be 80% and side-lap to be 25%;

(d) photography to be in a series of rectangular blocks bounded by lines of latitude and longitude;

(e) statoscope readings to be recorded for all photography.

18. It is appreciated that "dead" ground may result from super wide-angle photography in mountainous areas and that such photography is not really suitable for mosaicing. The plan, however, can be flexible enough to provide for special photography with another suitable camera in cases where such photography is absolutely necessary. It is appreciated also that the scale of 1/70,000 is somewhat large for 1/250,000 mapping but is suitable for 1/50,000. This scale is nevertheless recommended. The enormous advantages and savings which accrue from the use of super wide-angle photography make it the obvious choice.

19. The cost of aerial photography is dependent on the type of aircraft used, the disposition of airfields in relation to the areas to be photographed, the size and the grouping of the blocks to be photographed and on the scale of photography. Individual blocks of photography 6,000-8,000 square miles in extent, preferably covering a full 1/250,000 map sheet, are desirable. The cost of photography averages between 15/- and £1 per square mile in South Africa where Dakota aircraft are used, the aerodromes are within reasonable reach of the photo jobs and the blocks, although they tend to be on the small side, are usually conveniently grouped.

TOPOGRAPHICAL MAPPING

20. Countries with long-established survey and mapping organisations produce and maintain numerous map series on a wide variety of scales but it must be realised that this state of affairs has been built up over several decades and that it is quite impracticable for a developing country, starting virtually from scratch, to attempt to carry the same range. It is reasonable to set a similar objective as a long-term policy, but it is necessary to confine the first phase to absolute essentials.

21. It is recommended that the plan for the implementation of the policy regarding topographical mapping be:

(a) first phase: to cover the whole country as rapidly as possible with a 1/250,000 Topographical map series with 250 foot contours, running concurrently with but independently of, a 1/50,000 series with 50 foot contours. The 1/50,000 series in the first instance and until such time as the 1/250,000 series is completed, will be confined to the more developed areas and to those areas where it is known that early development will take place.

(b) second phase: the second phase will be implemented only when it will not jeopardise the early completion of the first phase. It will consist of the production of the 1/500,000 and 1/1M series by compilation from the 1/250,000 series, the progressive extension of the 1/50,000 series and the production of map series on a scale or scales larger than 1/50,000 in selected areas.

(c) third phase: the third phase will consist of the extension of the map series on scales of 1/50,000 and larger, the revision of existing maps as necessary, and of the expansion of the range of map series and special maps produced.

It will be noticed that the 1/250,000 map series is the smallest scale map which will be produced from de novo field work.

22. It is recommended that full use be made of the modern photogrammetric techniques of aerial triangulation and plotting of map manuscripts with the aid of stereoplotters. A battery of one first-order stereoplotter for aerial triangulation feeding five second-order stereoplotters for plotting, can complete between 6,500 and 7,500 square miles of 1/50,000 mapping per year, working one shift of normal office hours. Such a battery of six plotters represents a capital investment of about £35,000. Persons with a relatively high standard of education and an aptitude for the work are required as operators. Professionally qualified persons are required for the managerial posts. The advances made in electronic computers has renewed interest in the use of stereocomparators for aerial triangulation and much attention is being paid to this technique to-day, so the possible adoption of this method should receive consideration when the equipping of the photogrammetric section is being planned. The size of the photogrammetric section will depend on local circumstances regarding financial and manpower resources and on the mapping programme, besides which, a balance must be maintained between the production rates of the field survey and the photogrammetric plotting sections. For 1/50,000 mapping where the pencilled manuscript is inked-in by a tracer and not by the stereoplotter operator, the ratio can generally be taken as 1½ field units supplying field data and subsequently field-checking the manuscript, to one plotting unit working a single shift.

23. The pattern of photo ground control every 5 to 7 overlaps for aerial triangulation of strips for 1/50,000 mapping helps considerably in overcoming the difficulties of terrain and lack of access. This density can quite conceivably be reduced further if electronic computers are used for the adjustment of blocks of bridges. With this density, the photo ground control points can be fixed by triangulation, trilateration or by traverse employing electronic distance measuring devices from the primary triangulation framework. The heights of the ground control points can be determined by trigonometric levelling, spirit levelling or by properly controlled and executed barometric levelling using batteries of barometers.

24. It is recommended that the plotting of the map manuscripts from the aerial photographs be done to the scale and to the sheet lines of the published map. This plotting will be done in pencil and it is recommended further that the inking-in of the manuscripts be done by a woman tracer and not by the more highly skilled stereoplotter operator.

25. For various reasons which may include lack of capital and of suitable manpower, it may be difficult to establish and equip a section with stereoplotters and to staff it for some considerable time. As an interim measure to tide the organisation over this rather lengthy period of equipping the section and training the staff, resort may have to be made to some other method of map production. For this purpose the technique involving the slotted-templet for planimetric control, the contouring of spot-heighted photographs under a simple stereoscope and the plotting of the detail by means of a radial line plotter, can be considered. This method is applicable where there is a plentiful supply of manpower of a not very high standard of education because it lends itself to the distribution of the work amongst a number of people. The staff can be selected for their aptitude for performing one or other of the various operations and can be trained for and employed on that one operation only. The standard required of the field surveyor remains the same, whichever method is used. The density of the photo ground control and particularly of the spot heights for the contouring, requires

that virtually all the ground must be covered by the field surveyor, which is a drawback in difficult terrain. It requires also that plotting be done to a scale the same as or smaller than, that of the photographs, which would mean a review of the recommendation for the scale of aerial photography in paragraph 17(a). However, the method might be considered for the 1/250,000 mapping during the build-up period of the photogrammetric section.

26. The specifications for each map series, which are essential for any planned programme, can conveniently be divided into four interrelated parts covering details with respect to the following:

(a) the topographical features which will be shown on the series;

(b) the field survey operations and methods;

(c) the procedure for plotting the manuscripts;

(d) the manner in which the information will be shown on the published map, i.e. the specification for fairdrawing and printing.

LARGE SCALE ENGINEERING AND SPECIAL PLANS

27. This category of surveys does not fall within the scope of a paper on topographical mapping but brief mention must be made of such surveys and plans. The execution of such surveys should be the function of an organisation, or of organisations, other than that responsible for the geodetic survey and topographical mapping of the country.

28. The principle that subsequent surveys be connected to the national triangulation system applies equally well to this category. Since these surveys cover restricted areas for development purposes, it will be the duty of the geodetic survey to provide tertiary order triangulation in the areas of development, in order to make the connection of these surveys to the national system an economical proposition.

29. If suitable aerial photography is provided, modern photogrammetric methods can be used with advantage for large scale engineering plans.

FAIRDRAWING FOR MAP REPRODUCTION

30. The topographical information must be reproduced in a suitable form and in quantity so that it can be widely distributed. The reproduction of maps in quantity can best be done by the lithographic printing process, for which the map material has to be specially prepared. The map-user requires that the information be represented accurately and in such a way that the different topographical details can be distinguished readily. The use of different colours contributes to the ease of map interpretation. Colour separation fairdrawings are thus required as a step between the manuscript and the printing of the published map.

31. The three most common fairdrawing methods are:

(a) drawing with pen and ink on an opaque medium;

(b) drawing with pen and ink on a transparent medium;

(c) scribing with cutting tools on a coated transparent medium.

It is essential that a stable medium be used for each method. Aluminium in-

terlined drawing paper is used for (a) and suitable plastics for (b) and (c).

32. It takes many months to train a draughtsman to the standard of craftsmanship required for pen-and-ink fairdrawings. On the other hand, it takes three to six weeks to train a person for the scribing method, for which a co-ordination between hand and eye, sufficient to follow a line accurately, is the only skill required. It has been the experience of all organisations that the rate of production increases with the changeover to the scribing method. The scribing method is thus recommended.

33. When map sheets are so urgently required that the delay in publication occasioned by the colour-separation fairdrawings cannot be tolerated, the manuscript itself can be reproduced in monochrome as a preliminary printed edition of the final map after the essential marginal information has been added by the draughtsman.

34. An experienced draughtsman should be able to complete the colour separation fairdrawings for 1,000 square miles of 1/50,000 mapping per year.

CONCLUSIONS

35. A national framework of triangulation and height control and a series of topographical maps are a prerequisite for the orderly and efficient development of a country. It is thus necessary to create an organisation to prosecute the geodetic survey and topographical mapping with energy.

36. The organisation must have a stated policy. It must be laid down that the policy is to be implemented in phases so that the minimum needs of the country are met in the order of their importance.

37. The suggested order is as follows:

(a) first phase: full cover of the country with primary triangulation and precise levelling, aerial photography and 1/250,000 topographical mapping; 1/50,000 mapping in selected areas;

(b) second phase: extension of the secondary and tertiary triangulation and precise levelling and of the 1/50,000 mapping; compilation from existing maps of the 1/500,000 and 1/1M series; production of maps to scales larger than 1/50,000 in selected areas; special photography; map revision.

(c) third phase: map revision and such further undertakings as required.

38. The phases will merge into each other at appropriate junctures. Where the need can be proved, operations from the next phase may have to be undertaken out of turn, but these must be restricted to the absolute minimum.

39. The bulk of the resources in the first instance must be allocated to the first phase geodetic and aerial photography programmes because they are prerequisites for the mapping undertakings. In the course of time, more and more of the resources will be directed to topographical mapping until eventually each undertaking will be allocated a share commensurate with its needs.

40. The application of the modern techniques which have been suggested will not only result in optimum production but will also reduce the adverse effects on the rate of production caused by difficult terrain. The use of

helicopters for the transportation of field survey parties will speed up the work considerably by still further overcoming the difficulties of terrain.

41. A methodical programme of staff training must be introduced in order to develop the skills and to raise the standard of education to the level demanded by modern techniques.

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